High Intensity Neutrino Source Test Facility at Meson System Overview of Hazards

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Version 1.0

1 Version Info

Refer to this section to view changes made between different versions of this document. Major version number changes will involve changes in the physical layout of the facility. More safety factors will be included as the facility is improved.

1.1 Version 1.0

This is the original version of the document, and it evaluates the safety hazards in the RF power sources and component test area. Some of the devices included in this version are the 2.5 MW klystron, 10 kV pulse modulator, waveguide switch, waveguide distribution, and waveguide shutter. This version also discusses the hazards and protections associated with installing test components to the waveguide coax transition for high power RF testing.

2 Introduction

The purpose of the High Intensity Neutrino Source (HINS) program is to demonstrate the feasibility of a new design for a high energy, high intensity H- accelerator. The projected final design of the accelerator will have H- beam accelerated to 8 GeV, stripped, and injected into the Main Injector for acceleration into the neutrino target. There are two major aspects of this accelerator that make it different from any existing linear accelerator: multiple cavities are driven from a single high power source, and the transition from normal conducting to superconducting cavities occurs at a low particle velocity ($\beta = 0.145$). The first aspect implies that fine control of the phase and amplitude at individual cavities must be performed at high power levels. The second aspect implies that low velocity, superconducting cavity structures that have never been used to accelerate beam are necessary.

The test facility at Meson for the HINS program will consist of a linear accelerator up to 60 MeV of beam energy. The beam-line components for the facility will include an H- ion source, an RFQ, a section of room temperature cavities and superconducting solenoids, and up to three cryomodules with superconducting cavities and solenoids. The facility will also include all of the RF power and distribution, power supplies, and controls necessary to accelerate the beam.

In the first phase of the program, it will be necessary to test many of the individual high level RF components to insure that they meet the specifications needed for accelerating beam. These components include cavities, couplers, phase shifters, and tuners. Each

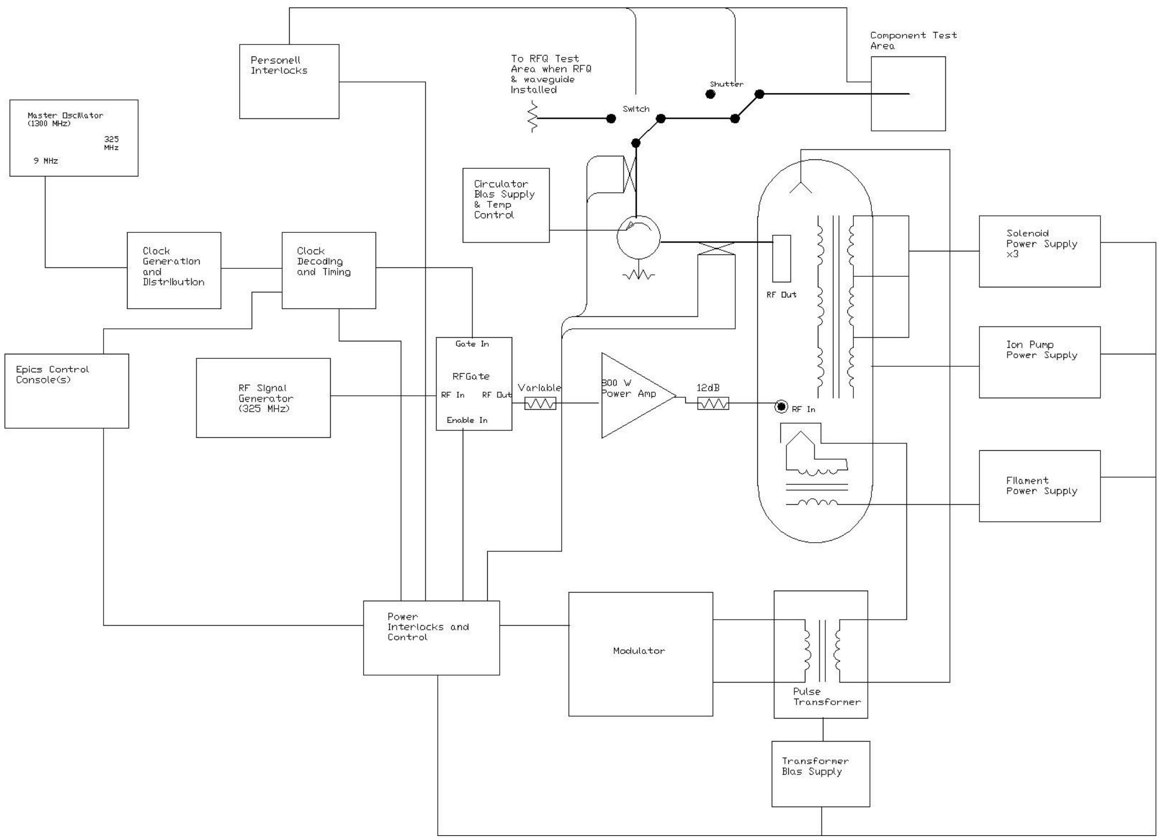

Figure 1: Block diagram of HINS Meson RF power and distribution facility. Bold lines represent waveguide and components.

time a different component is tested, it will take full control of the RF power source. However, because of the different hazards involved with testing components, different test will be performed in different physical locations of the facility. This implies an RF distribution with a series of switches to direct the flow of RF power.

2.1 Block Diagram of RF Power and Distribution System

The high power RF system is centered around the 2.5 MW klystron and its support equipment. The pulsed bias of the klystron is provided by a charging supply, modulator, and pulse transformer combination capable of 100 kV pulses. Other power supplies control the filaments and solenoids of the klystron. A remote controlled signal generator acts as the source of the RF signal. The signal goes through a gate switch to control rep-rate and act as an interlock control. The signal then goes through a variable attenuator to control amplitude and enters a 800W power amplifier followed by a 12dB attenuator, before going to the klystron. The output of the klystron enters WR-2300 waveguide which is connected to a circulator. The reverse output of the circulator is terminated with a water cooled, 45 kW(ave.) load, and the forward output is connected to an RF switch.

The switch directs the RF power to either a 45 kW termination or waveguide to the component test area. At the component test area, there is a waveguide shutter followed by a waveguide to coax transition.

2.2 Physical Layout of System

The test facility is located in the southeast corner of the Meson building, just east of the Meson beam line. The modulator components and the klystron all form a line just east of the testcryostat enclosure (see figure 2). Interlock, control, and power supply racks are located across from the pulse transformer. The waveguide and waveguide components around the klystron are located 12’ off the ground. The waveguide altitude drops to 1’ just before the bend to the component test area. The area around the waveguide to coax transition is surrounded by a 10’ x 10’ interlocked cage.

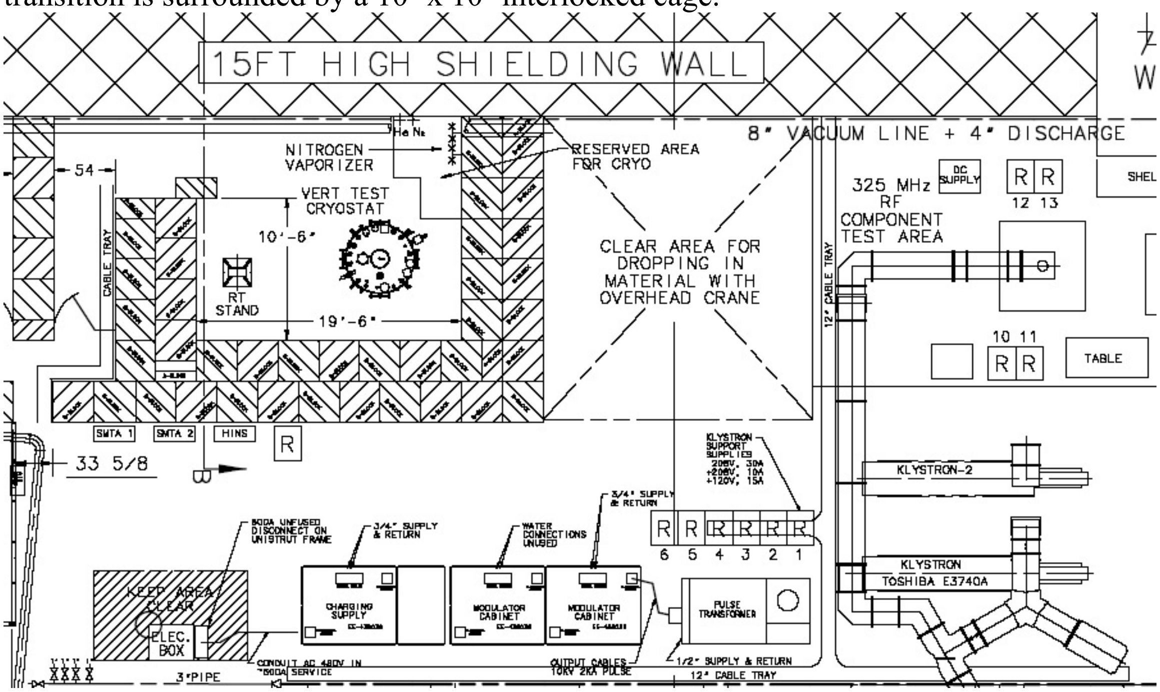

Figure 2: Physical layout of Meson-PD facility.

2.3 Operational Specifications

This section contains a summary of the pertinent operational specifications used to gauge personnel safety.

	Max
Operating Frequency	325 MHz
Klystron Peak Power	2.5 MW
Klystron Average Power	78 kW
Electromagnet Current	20 A
Electromagnet Voltage	375 V
Klystron Peak Beam Voltage	100 kV
Modulator Peak Voltage	10 kV
Ion Pump Voltage	3.9 kV
RF Driver Amp	800 W

Table 1: Absolute maximum ratings for key operational specifications.

2.4 Modes of Operation

There are two modes of operation in the configuration described above. In the first mode, the RF switch is positioned to run into the dummy load only. This mode is used for klystron conditioning and testing. In the second mode, the RF switch is positioned to run into the component test area. This mode is used to test RF components at higher power levels.

3 Hazard Analysis

3.1 Environmental

The Meson facility has issues with environmental control of the building. Hopefully, some of the major issues will be dealt with when the roof is repaired. Until then, measures need to be taken to prevent damage to equipment.

3.1.1 Precipitation

The Meson facility roof leaks when it rains or snow begins to melt. This precipitation can short out electrical equipment it comes into contact with. To remedy the problem, the RF power source and component test areas of the HINS facility at Meson is covered with corrugated aluminum roofing to shed the water from the ceiling of the building.

3.1.2 Extreme Temperatures

There is no temperature regulation in the northeast corner of the Meson building. The temperatures can be quite extreme compared to a normal office environment. To keep from damaging the klystron, the air temperature in the room must be maintained between 0 - 40°C. This temperature range is easily attainable with the temperature control equipment in the building when the building has power.

3.2 Mechanical

There are no exposed moving parts in the RF source and distribution components of the Meson/HINS facility. The only hazards are static.

3.2.1 Large Suspended Objects

There are massive waveguides and waveguide components resting 12’ above the ground. In order to operate and perform regular maintenance on the system, people will need to walk and work under the components. The waveguides and components are mounted on Unistrut, and the entire support system has been inspected and approved by Accelerator Division and Technical Division structural experts. No RF system operation or maintenance will be permitted while changes are being made to overhead components or the support structure.

3.2.2 High Elevation Access

Enclosures for wiring and some controls of the waveguide switch and circulator are located on top of each of the components at a height of about 15’. Maintenance of the circuits of these enclosures may be required. Care must be taken to use proper ladders or hoist equipment when accessing the enclosures.

3.3 Electrical Contact

There are no exposed high voltage electrical contacts or components on the HINS system during operation. All exposed contacts are enclosed in power supply chassis or cabinets with interlocked access doors. There will be occasions where internal components of high voltage supplies will need maintenance. Protections and procedures need to be in place for safe access into these supplies.

3.3.1 Modulator LOTO

The klystron modulator consists of three separate components: the charging supply, the pulse modulator, and the pulse transformer. Both the charging supply and pulse transformer are enclosed in chassis or containers that are screwed/bolted shut. The modulator has maintenance access panels and a door, but these accesses are interlocked to cut power to the modulator and short out any stored charge. Because of the large amount of stored energy in the klystron modulator, a special LOTO procedure describes the proper shutdown process for accessing the modulator and its components for maintenance. All maintenance of the modulator must be performed by personnel trained in this LOTO procedure by a modulator expert.

3.3.2 Klystron LOTO

The klystron itself has no exposed wiring, with all power entering the klystron through standard insulated cables and connectors. The only access area of the klystron that is interlocked is the lead shield door, and this is for protection against ionizing radiation (see section on ionizing radiation hazards). Shutting down the klystron for maintenance requires disabling multiple power supplies in the proper sequence. Therefore, a special LOTO procedure describes the proper shutdown sequence for the klystron. All maintenance of the klystron and its supplies must be performed by personnel trained in this LOTO procedure by a klystron expert.

3.3.3 Standard LOTO for Other Supplies

All other energized components and power supplies in the system are self contained, have a single, lockable power source, and have little or no stored energy. Maintenance of these components require standard LOTO training.

3.4 Non-ionizing Radiation

One of the main hazards of the HINS RF distribution system is accidental personnel exposure to high power RF waves traveling through the air. The system must be designed to keep the 78 kW of potential average power from the klystron from reaching people with a density of more that $1 mW/cm^2$. The possible sources of exposure are: leaks in the waveguide distribution system, open connections in the component test area, or broken components connected in the component test area. Details of the specifications and remedies for the RF exposure hazards are in a separate document, but a summary is contained here.

3.4.1 Certification of Fixed Waveguide

All permanent RF distribution components and waveguide must pass an inspection and low power test before being used to distribute high power RF. The inspection will look for visible openings in the waveguide connections and reliability of the support structure. The waveguides will be filled with low power RF signals, and an antenna will be used to check for any leakage around them.

3.4.2 Waveguide Leak Detectors

A number of RF detectors will be placed at waveguide junctions to insure that leaks do not develop over time. These detectors are interlocked to disable the drive to the klystron if they sense RF levels much greater than the ambient surroundings.

3.4.3 Enclosed/Shielded Component Test Area

To protect the area around the component test area from stray RF due to open connections and component malfunction, a 10’ x 10’ gated, interlocked, fenced enclosure surrounds the test area. The fenced enclosure serves two purposes: it keeps passersby away from any components under tests, and it acts as an RF shield and distance barrier to workers and passersby in case of RF leakage within the enclosure. No RF is permitted to run to the component test area unless the fenced enclosure is clear, closed, and locked.

3.4.4 LOTO of Component Test Area

There will be times when the klystron will be operating into the terminated end of the switch while personnel are configuring the component test area. To insure that no RF can reach the component test area, a waveguide shutter can be closed upstream of the test area. This shutter can be locked into place, and its position is interlocked. If the waveguide shutter is not closed, and the fence area is not interlocked, the RF power to the klystron is disabled. A special LOTO procedure defines how to properly access the component test area. All personnel who enter the fence enclosed component test area must be trained in the LOTO procedure by a component test area expert.

3.4.5 Test Area Leak Detectors

As a backup to the LOTO procedures and interlocked enclosure, RF leak detectors are located within the enclosed component test area. If these leak detectors sense RF above the safe levels in the enclosure, they will disable the klystron RF.

3.5 Ionizing Radiation

The klystron accelerates electrons to a relatively high voltage to amplify RF signals carried by the electrons. The process of accelerating electrons in a vacuum produces substantial x-rays. Proper precautions must be taken to insure that personnel are not exposed to harmful x-rays during klystron operation.

3.5.1 Klystron Lead Shield

The klystron as shipped from Toshiba Corp. includes a lead shield around the electron collector. This shield should sufficiently protect any personnel around the klystron during its operation. The shield contains a latched door for maintenance access to the collector of the klystron. This door is interlocked to disable the modulator power supply if the door is opened. The klystron collector area will be inspected and certified by monitoring x-rays as the power level of the klystron is increased.